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LITTER DECOMPOSITION BY ARTHROPODS IN UNDISTURBED AND INTENSIVELY MANAGED MOUNTAIN BRUSH HABITATS

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ABSTRACT.—The population dynamics and decomposition activities of litter arthropods in an unmanaged sagebrush/bitterbrush habitat in southeastern Wyoming were assessed in 1986. The effects of sagebrush/bitterbrush management practices on litter arthropod communities and the role of these communities in decomposition were also assessed. Insecticide applications were used to selectively exclude arthropods in order to determine the ecological impact of these detritivores. Application of a herbicide, 2,4-D, was associated with increased arthropod populations for 30 days following treatment. Mowing increased arthropod densities at two different times, 10–30 days and 50 days posttreatment, perhaps as a result of functional and numerical responses by litter arthropods. Elimination of arthropods from otherwise undisturbed shrub habitats by the use of broad-spectrum insecticides reduced the rate of litter decomposition during the growing season, indicating that these organisms play an important role in decomposition and nutrient cycling.

Sagebrush (*Artemisia* spp.)-dominated lands of the western United States cover more than 100 million ha (Beetle 1960). Sagebrush is considerably less palatable to domestic animals than are many other range shrubs (Powell 1970). Consequently, burning, herbicide applications, and mowing are widely used in an attempt to reduce densities of this plant (Powell 1970). While it is apparent that such disturbances in sagebrush communities enable economically more desirable grasses to populate range areas, little is known regarding the impact on arthropod populations and the resultant effects on decomposition and nutrient cycling.

Many studies have shown that habitat disturbance influences arthropod densities, species distribution, and community diversity of grassland ecosystems (Blocker et al. 1971, McDaniel 1971, Morris 1971, Lavigne and Kumar 1974, Kumar et al. 1976). Although virtually nothing is known concerning the role of arthropods in the ecology of sagebrush/bitterbrush habitats, studies of other ecosystems have shown that during disturbance and succession, changes in the types and abundance of plants and the associated litter affect arthropod diversities (Murdoch et al. 1972, Southwood et al. 1979).

Studies of litter decomposition have been conducted in undisturbed ecosystems including desert, prairie, and forest but not in sagebrush/bitterbrush habitats. Several studies (Strojan et al. 1987, Schaefer et al. 1987, Whitford et al. 1986) have revealed either short- or long-term correlations of rainfall with litter decomposition in desert habitats. However, Schaefer (1985) showed that organic matter, but not moisture, affected litter fauna. Other studies (Santos et al. 1984, Santos and Whitford 1981) on desert habitats used a single application of chlorodane to individual litter bags to demonstrate that litter decomposition declines by 24–53% in the absence of arthropods. Vasobrinch et al. (1979) found that soil mites, microbial activity, and rainfall increased decomposition in shortgrass prairie.

The objectives of this study were to determine the effects of intensive mountain shrub management practices on populations of decomposer arthropods and to ascertain the role of these arthropods in litter decomposition throughout a season.

MATERIALS AND METHODS

This study was conducted on a sagebrush (*Artemisia tridentata*) and bitterbrush (*Purshia tridentata*) habitat located at an elevation of 2,400 m, 12 km southeast of Saratoga, Carbon County, Wyoming. Soils are of the North Park Formation of brown, sandy loams developed on loess, limestone, sandstone, and

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tuff. Rainfall and temperature were recorded throughout the study period. The study area averages 480 mm precipitation per year, with most of the moisture being provided by snow; 102 mm of rainfall was measured during the study period. The mean annual temperature is 10.2 C, and temperatures ranged from 21.0 to 27.0 C during the study period.

Within the study site, twelve 4-ha blocks were randomly chosen from areas that had similar vegetation and soil characteristics. Habitat manipulation consisted of mowing four blocks to a 20-cm stubble height or applying 2,4-D butyl ester in water at a rate of 0.91 kg per acre to four blocks in May of 1986. Four blocks were left untreated to be used as control plots.

Two insecticides, carbaryl (1.68 kg/ha) and malathion (1.4 kg/ha), were alternately applied every two weeks to half of each treatment and control block. The other halves of the blocks were left unsprayed and served as controls for comparison of litter decomposition. These broad-spectrum insecticides provided a reduction in the total arthropod population. By using half-blocks (2 ha) as the smallest units of treatment plots, we reduced migration of arthropods into and around litter bags; this prevented feeding before the insecticide could affect arthropods, a potential problem with treated litter bags.

Ten nylon litter bags, 15 × 15 cm with 1.5-mm mesh, were filled with 20 g of ground litter (Webb 1977) from each site. They were then placed in open (sagebrush-free) and closed (sagebrush-canopied) areas within each half-block (insecticide treated and untreated) in the last week of May 1987. The litter bags were collected the first week of September 1987 and weighed to determine the amount of decomposition. The total decomposition period studied was 100 days.

Litter decomposition rates were also determined by collecting twenty 0.5-m^2 samples of litter from each of the insecticide-treated and untreated half-blocks. Arthropod densities were determined by collecting eighty 0.25-m^2 plots of litter from each half-block every 10 days throughout the study period. Arthropods were separated from litter material in the laboratory by Berelese funnels.

Differences in arthropod densities following application of herbicide and differences in litter biomass and rate of decomposition by mowing were analyzed by ANOVA and a least significant difference post-ANOVA test. Correlations of rainfall, temperature, and arthropod densities with litter decomposition were calculated with step-wise regression. Chi-square was used to determine management practices on total canopy cover.

RESULTS AND DISCUSSION

Litter Production and Decomposition

There was no significant ($P > .10$) linear correlation of rainfall ($r^2 = .42$) or temperature ($r^2 = .38$) with litter decomposition. Because the growing season (May through September) is short, dry, and has fairly constant temperatures, this is not a surprising result.

Litter biomass remained virtually constant in control plots throughout the course of the study. Mowing increased the litter biomass by 6.4-fold, and herbicide application increased litter biomass by 3.0-fold. Since there may be a delay of a year or more before sagebrush leaves drop in herbicide-treated areas, these results may underestimate long-term litter biomass production for the latter treatment.

Brush management practices reduced the canopy cover of treated blocks, while unmanaged blocks showed no change in shrub canopy cover. There was a 40.9% decrease in shrub cover in herbicide-treated blocks and a 24.1% decrease in shrub cover in mowed blocks (Table 1).

Litter decomposition for this study area ranged from 24% to 53% for the 100-day period, depending on the brush management strategy and insecticide treatment (Table 2). Differences in decomposition in litter bags as a function of management and treatment were reflected in the loose litter samples (Table 3). Decomposition rates in undisturbed areas were comparable to the 51–68% losses per growing season found on sites in Idaho (Murray 1975), 50% litter decomposition in an area of Washington (Mack 1977), and decomposition losses of 43–53% near Reno, Nevada (Comanor and Staffeldt 1978).

Effects of Shrub Management on Litter Arthropods

Acari, Collembola, and Thysanuran populations (Table 4) fluctuated throughout the first 50 days and then remained relatively constant for the remaining 50 days of the study

TABLE 1. Effects of brush management practices on percent canopy cover.

Treatment	Year[a]	
	1985	1986
Unmanaged	28.1a	28.1a
Herbicide	29.6a	17.5b
Mowed	31.6a	24.0b

[a]Means for a parameter followed by different letters differ significantly between years ($P < .05$; chi-square). N = 60.

TABLE 2. Effects of shrub management and insecticide treatments on percent decomposition in litter bags in a mountain brush habitat.

		Management practice[a]		
Habitat	Insecticide	None	Mow	Herbicide
Open	Present	32.9Aa	50.8Ba	28.7Aa
	Absent	53.0Ab	23.5Bb	37.6Ab
Covered	Present	29.0Aa	47.6Ba	51.0Ba
	Absent	53.0Ab	51.2Aa	44.8Aa

[a]Litter biomass means across insecticide treatments and within habitats and management practices followed by different lower-case letters differ significantly ($P < .05$). Litter biomass means across management practices within the same habitat and insecticide treatment followed by different upper-case letters differ significantly ($P < .05$).

TABLE 3. Effects of shrub management and insecticide treatments on litter biomass ($\text{g}/0.5\text{m}^2$) in a mountain brush habitat.

		Management practice[a]		
Habitat	Insecticide	None	Mow	Herbicide
Open	Present	17.9Aa	23.5Aa	65.1Ba
	Absent	8.8Ab	56.2Bb	25.9Cb
Covered	Present	135.3Aa	74.4Ba	82.6Ba
	Absent	7.7Ab	56.6Ba	101.5Ca

[a]Litter biomass means across insecticide treatments and within habitats and management practices followed by different lower-case letters differ significantly ($P < .05$). Litter biomass means across management practices and within the same habitat and insecticide treatments followed by different upper-case letters differ significantly ($P < .05$).

(Figs. 1–4). Mite densities were usually lower in open areas (i.e., intershrub spaces) than in closed areas (i.e., under shrub canopy). But Collembola densities were nearly the same in litter in open areas as in closed areas or somewhat higher.

The herbicide treatment increased ($P < .05$) the abundance of litter arthropods for 30 days in both open and canopy-covered plots following treatment (Figs. 1–4). Because complete leaf drop following herbicide treatments is often delayed for a year or more, litter production may not solely account for the changes in arthropod abundance. The increase in abundance was primarily due to fungivorous mites. Degradation of 2,4-D increases fungal growth (Klingman et al. 1982), and this could increase the population density of litter decomposers (e.g., fungivorous mites and springtails). Since 2,4-D may degrade within two weeks of application (Meister 1987), the timing of the observed increase in arthropod populations is consistent with the indirect consequences of herbicide degradation. Corresponding to the increased populations of litter arthropods in herbicide-treated plots was a noticeable ($P < .10$) increase in litter decomposition rate. After 30 days, the arthropod population densities in herbicide and control areas did not differ greatly ($P > .10$); thus, the effect of 2,4-D on arthropod decomposers was apparently short-lived.

Mowing shrubs significantly increased ($P < .05$) litter arthropod populations for 30 days following treatment (Figs. 1–4). There was a significant increase ($P < .05$) in the population 40–50 days posttreatment, as well. The initial increase in arthropods was probably a result of immigration due to the sudden increase in resource (litter) availability. This type of immediate increase as a result of changes in the behavior of organisms has been termed a functional response in discussions of predator-prey dynamics (Price 1975). The later population explosion may have been a result of an increase in reproduction supported by an abundance of resources (litter). This type of time-lagged increase as a result of enhanced reproduction of the organisms has been termed a numerical response (Price 1975). Interestingly, the increases in litter arthropod populations were not clearly associated with an increase in litter decomposition.

Effects of Arthropods on Litter Decomposition

Insecticide application decreased litter detritivores by 78% in unmanaged blocks and 76% in mowed and herbicide treated-blocks (Table 5). The application of carbaryl and malathion on mowed, herbicide-treated, and undisturbed plots generally decreased litter decomposition (Tables 2, 3). Litter decomposition in undisturbed plots significantly decreased ($P < .05$) in both open and closed areas following insecticide treatments. Thus, litter arthropods appear to have an important role in litter decomposition in undisturbed sagebrush habitats. Coinciding with results of our study, Barret (1968) reported a large

TABLE 4. Impact of mountain brush management practices on density (no./sample) of litter arthropods in unmanaged (U), mowed (M), and herbicide-treated (H) plots.

Taxon	Time posttreatment[a]											
	0 days			10 days			20 days			50 days		
Habitat	U	M	H	U	M	H	U	M	H	U	M	H
COLLEMBOLA												
Orchesella hexfasciata Harvey												
Open	1a	2a	1a	1a	8a	7a	2a	56b	7a	1a	33b	29b
Closed	1a	1a	1a	1a	8b	8b	1a	9b	7b	1a	74b	39c
Isotoma viridis (Bourlet)												
Open	11a	10a	12a	12a	15a	13a	10a	11a	23b	22a	21a	21a
Closed	19a	19a	18a	17a	16a	16a	24a	36b	20a	34a	37a	33a
Onychiurus aramatus Tullberg												
Open	13a	15a	14a	14a	20b	13a	29a	31a	39b	36a	49b	32a
Closed	21a	20a	21a	17a	17a	16a	33a	29a	35a	29a	34a	31a
Bourtiella hortennis (Fitch)												
Open	4a	5a	4a	4a	3a	21b	7a	5a	2b	5a	6a	6a
Closed	2a	3a	3a	3a	26b	3a	6a	29b	6a	10a	83b	12a
ACARI												
Gustavia microcephala (Nicolete)												
Closed	9a	10a	9a	10a	72b	51b	10a	8a	6a	10a	5b	4b
Peloribates europaeus Willman												
Open	10a	11a	10a	15a	12a	13a	14a	15a	32b	18a	9b	12b
Closed	54a	49a	50a	49a	179b	40a	59a	162b	62a	63a	41b	39b
Peloribates sp. A												
Closed	1a	2a	2a	1a	1a	34b	1a	1a	30b	2a	25b	54c
Peloribates sp. B												
Closed	38a	43a	41a	42a	17b	63c	39a	19b	72c	40a	19b	21b
Ophidiotrichus sp.												
Open	29a	27a	27a	32a	14b	18b	30a	21b	15b	34a	10b	2c
Zygoribatula sp. A												
Open	49a	41a	57a	54a	78b	59a	74a	82a	81a	89a	193b	99a
Closed	90a	81a	83a	101a	115a	153b	111a	109a	149b	143a	162a	210b
Zygoribatula sp. B												
Open	4a	5a	5a	7a	9a	8a	11a	15b	16a	10a	19b	24b
Closed	8a	7a	8a	10a	18b	11a	19a	12b	31c	24a	33b	31b
Zygoribatula sp. C												
Closed	8a	8a	6a	9a	0b	15c	11a	0b	24c	10a	0b	38c
Ledermuelleria pectinata (Ewing)												
Closed	0a	0a	0a	0a	15b	0a	0a	29b	0a	0a	38b	0a
Xenillus sp.												
Closed	15a	14a	14a	30a	0b	45c	39a	0b	96c	41a	0b	108c
THYSANURA												
Lepismatidae												
Open	2a	1a	2a	3a	3a	1b	3a	3a	1b	4a	3a	1b
Closed	4a	3a	3a	4a	3a	2b	5a	6a	1b	7a	8a	4b

[a] Means within a posttreatment time for a species followed by different letters differ significantly ($P < .05$).

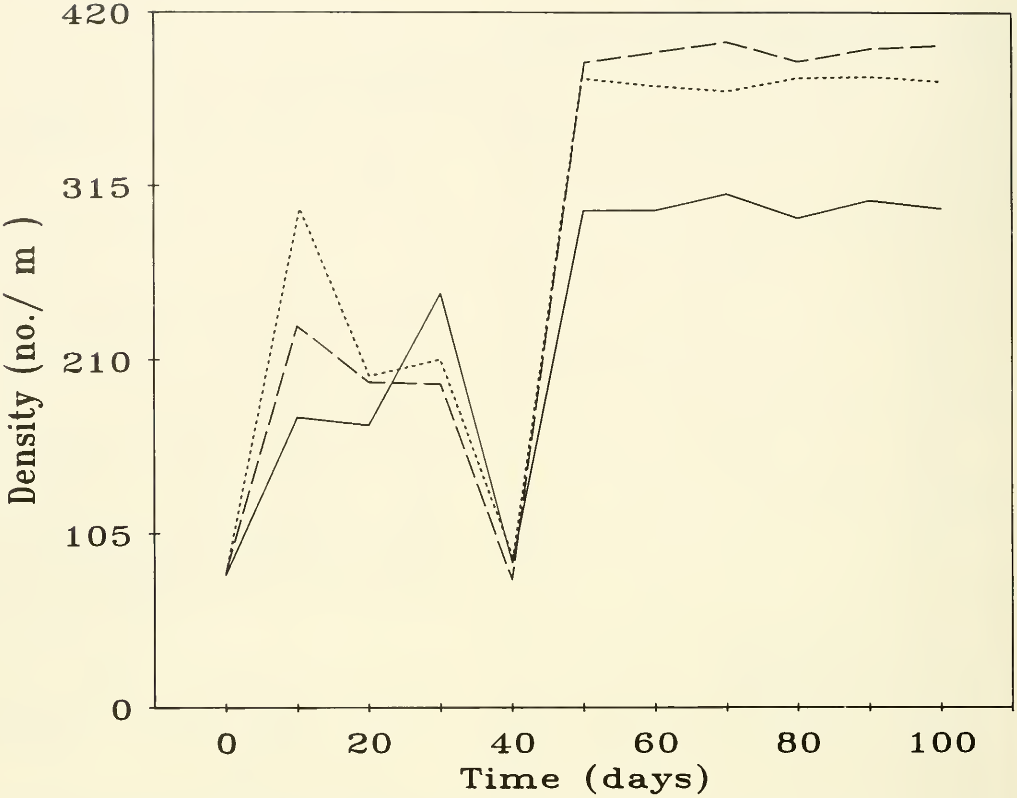

Fig. 1. Density of litter and soil mites in open areas in mountain brush habitats that were untreated (____), mowed (- - - -), or herbicide treated (— — —).

decrease in litter decomposition following application of carbaryl in a grassland habitat; the effects on arthropod abundance lasted only a few days following a single insecticide treatment. These treatments, which adversely affect arthropod populations, may be expected to result in alterations of nutrient availability and cycling (Christiansen 1989); the effects of such treatments will likely be delayed or long-term in nature but should be seriously considered in any shrub management program.

Insecticide applications in mowed plots decreased ($P > .10$) litter decomposition under sagebrush but significantly increased ($P < .05$) decomposition in open, grassy areas. Conversely, herbicide-treated plots showed a significant decrease ($P < .05$) in litter decomposition in open plots and an increase ($P > .10$) in decomposition in closed areas following insecticide applications. The anomolous, significant increase in litter decomposition in open microhabitats of insecticide-treated, mowed plots could have been the result of two interacting factors. The litter accumulated in open areas may have reduced the penetration of insecticides, and the availability of sulfur and phosphorous from the degradation of carbaryl and malathion may have accelerated decomposition (Melnikov 1971). These elements are a main source of energy for fungal and bacterial litter decomposers, and these organisms may have been of primary importance in the increased decomposition rate.

Decreases in the abundance of litter arthropods caused by insecticide applications generally lead to significant decreases in litter decomposition. In some instances, insecticides may indirectly facilitate litter decomposition by providing essential nutrients to fungal and bacterial decomposers. Given the significant effects of insecticide applications on the decomposition of litter by arthropods, the widespread use of these compounds in controlling rangeland insects should be

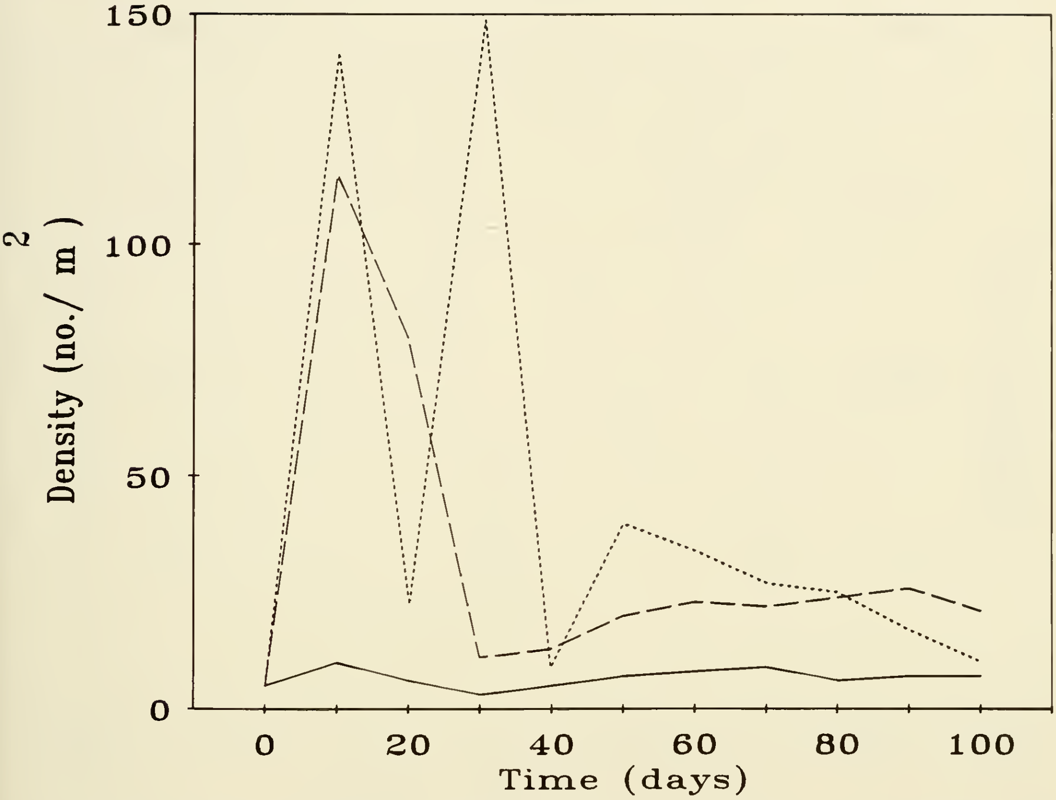

Fig. 2. Density of litter and soil collembolans in open areas in mountain brush habitats that were untreated (____), mowed (- - - -), or herbicide treated (— — —).

TABLE 5. Effects of insecticide treatments on litter arthropod detritivore population densities (no./m^2) in unmanaged, mowed, and herbicide-treated blocks.

	Unmanaged[a]		Mowed		Herbicide	
	con	trt	con	trt	con	trt
Acari	395	87	595	148	643	154
Collembola	42	9	98	25	33	8
Thysanura	4	0	5	0	3	0
% decrease	78		76		76	

[a]con = untreated control; trt = treated with insecticides.

reevaluated. Although many pest insects are frequently not abundant in mountain shrub habitats (e.g., rangeland grasshoppers) and rangeland pests are not treated as intensively as in our study, the inclusion of these habitats in large-scale treatments is a matter of concern. The long-term impact of reducing litter arthropod populations is not known at this time, but it is reasonable to assume that nutrient cycles within the habitat will be disrupted.

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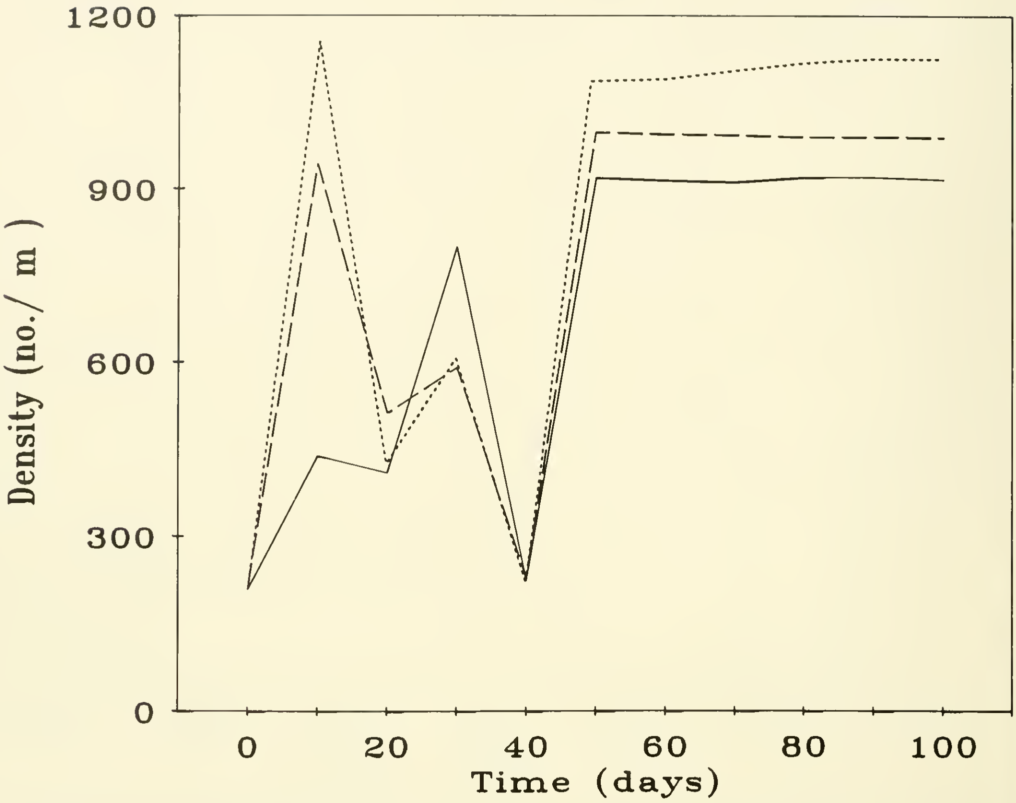

Fig. 3. Density of litter and soil mites in closed areas in mountain brush habitats that were untreated (____), mowed (- - - -), or herbicide treated (— — —).

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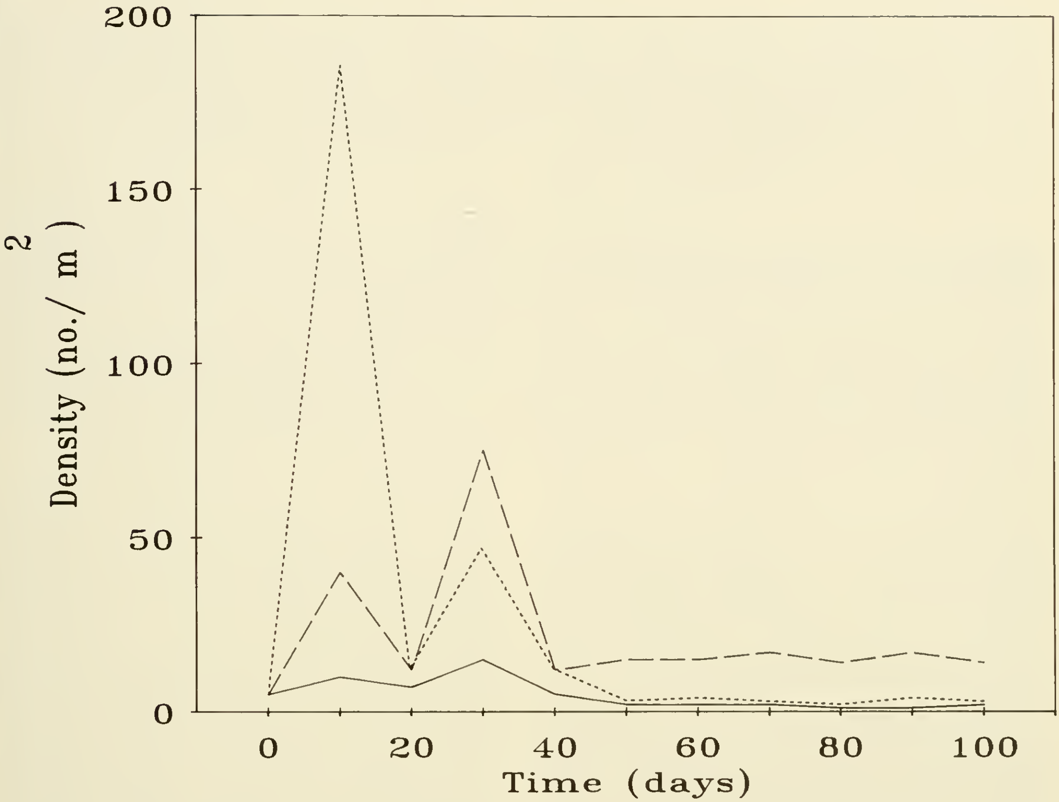

Fig. 4. Density of litter and soil collembolans in closed areas in mountain brush habitats that were untreated (____), mowed (- - - -), or herbicide treated (— — —).

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